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AC CONDUCTIVITY AND DIELECTRIC STUDY OF THE POLYESTER REINFORCED BY AL/CNT:ZN/AL NANOCOMPOSITE

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Abstract

In this study, composites of carbon nanotubes and zinc matrix have been fabricated by a powder metallurgy method. Firstly, CNT and Zn powders with sizes in the range of (4.5-6.7) nm, respectivel are dispersed at various weight contents (in the range of (2.0% -.1.0 %) in polyester polymer as solvent to get (polyester /CNT-Zn) Nano composite of about 2 mm thickness. The effects of different multi-walled carbon nanotubes (CNTs) contents on the ac conductivity and dielectric properties of the composites were investigated. Ac conductivity measurements of multi-walled carbon nanotubes (CNTs) reinforced polyester have been evaluated. AC conductivity was examined in the frequency range from (100-400k) Hz at ambient temperature.An enhancement of Ac-conductivity, in accordance to percolation theory, was evidenced increasing the weight content of the conductive Nano-filler .The experimental results indicate that the frequency dependent behavior of CNT-Zn /polyester Nano composite can be modeled by R-C circuit, permittivity of material increase with increasing of CNT content. .Also, the results showed that the addition to the zinc matrix of 1% by volume of carbon nanotubes caused increases in the ac conductivity.

Keywords:A.C Conductivity, NanComposite Polymer, Dielectric Constant.

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1. Introduction

Investigations into conductive polymers have attracted great scientific interest because of their high application potential [1–3].from these materials, the CNT-based composites, which may be one of the most promising applications, have been intensively studied using different matrix materials, polymers, ceramics and metals[4].Polymer/carbon nanotube (CNT) composites are expected to have good process ability characteristics of the polymer and excellent functional properties of the CNTs. The critical challenge, however, is how to enhance dispersion and alignment of CNTs in the matrix. Here, we review recent progress and advances that have been made on: (a) dispersion of CNTs in a polymer matrix, including optimum blending, in situ polymerization and chemical functionalization; and (b) alignment of CNTs in the matrix enhanced by ex situ techniques, force and magnetic fields, electro spinning and liquid crystalline phase-induced methods. In addition, discussions on mechanical, thermal, electrical, electrochemical, optical and super-hydrophobic properties; and applications of polymer/CNT composites are included. Enhanced dispersion and alignment of CNTs in the polymer matrix will promote and extend the applications and developments of polymer/CNTnanocomposites [5]. The unique structure and excellent properties of carbon nanotubes (CNTs), (both single-walled and multi-walled(SWCNTs and MWCNTs)) has prompted intensive study for potential engineering applications, for example for CNT conductive composites, in the electronics, automotive and aerospace sectors with uses such as electro static dissipation [6]. The presence of conductive particles in an insulating material changes the composite system's electrical conductivity. For low filler content, the conductivity remains at the level of the unfilled insulating matrix. However, with increased conductive load, an abrupt and significant increase occurs at critical filler content. The critical concentration (or percolation threshold) determines the insulator-to-conductor transition. Carbon nanotubes (CNTs) have excellent electrical, mechanical and electromechanical properties. When incorporated into polymers, high electrical conductivity can be achieved in the formed nanocomposites even at very low CNT volume fraction (often below 1% wt). In addition, the electrical conductivity of the CNT nanocomposites is sensitive to mechanical strain, resulting in potential applications for strain sensing .The electrical behavior of CNT based polymer nanocomposites has been extensively explored with emphasis on several aspects, such as insulator-conductor transition (percolation threshold) and the relationships between conductivity and function of filler volume ratio, CNT orientation and dispersion, CNT treatment and processing conditions [7].In general, the electrical behavior of polymer/CNT composites can be explained according to percolation theory and tunneling effect. However, despite broad investigation on CNT polymer nanocomposites, fundamental understandings of these properties are still lacking, such as percolation mechanism. Also, the effects of thermal strain, loading modes and CNT fictionalization on the electromechanical response are yet to be fully elucidated. To this end, further experimental and theoretical investigations are needed. In this work multi-walled CNT/polymer nanocomposites were successfully fabricated. Their electrical behavior, in particular the conductivity under DC (direct current) and AC (alternating current) conditions were investigated [8].

Experimental Part

CNT –Zn powder can be used for the preparation of nanocomposites Polyester polymer matrix was prepared by mixing resin and hardener in ratio 3:1.CNT powder with sizes in the range of (4.5-6.7) nm was prepared by arc discharge technique .This powder is dispersed with Zinc powder in polyvinyl alcohol (PVA) solution methanol solution under magnetic agitation to reduce the maximum size of the aggregates. After the methanol is evaporated, we obtained CNT-Zn powder which is directly added to polyester resin hardener mixture .Finally the samples were placed between two metal plates under pressure to reduce porosity forming during hardening. Before electrical measurements, the surfaces of the specimens were mechanically polished to minimize the influence of surface flaws, mainly the porosity. The prepared samples were coated using masking system using Al electrodes of thickness 200nm were evaporated from tungsten filaments for fabricating Al/(CNT-ZN)- Polyester/Al sandwich structures. The capacitance was measured using Hp. 4274 A and 4275 A programmable automatic RCL (model, Hewlett. Packard) meter at different frequency range from 100Hz-400 kHz at room temperature in a container for the determination of dielectric constant. Ac

measurements were also carried out using similar equipment at varying frequencies these were purposely for the establishment of graphs of capacitance, dielectric loss and conductivity as functions of frequency.

Result and Discussion

Fig.1 shows the variation of capacitance as functions of frequency for CNT-ZN/Polyester at different CNT concentration . Noticeably, the fall in capacitance is very rapid in the initial frequency, starting between 100Hz-4KHz and then slowly decreases at a frequency 4KHz-400KHz for all the samples. These results give the approximate dielectric constants which vary with temperature in decreasing manner.

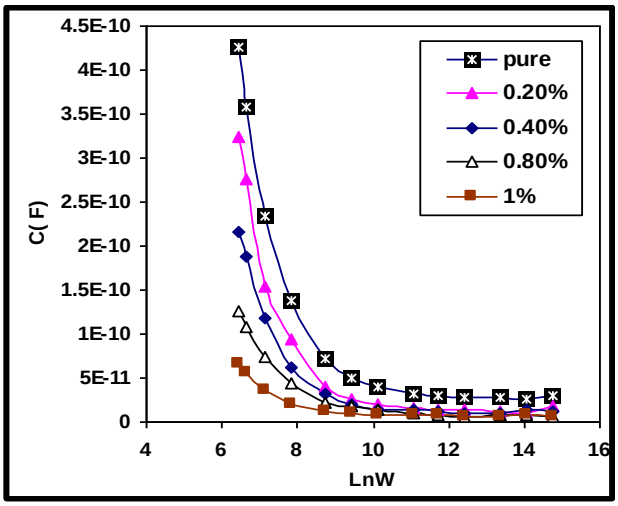

Fig.1: Variation of capacitance with frequency at different concentrations of CNT-Zn /polyester composite

Fig.2 shows the dielectric loss or tan□ was obtained at different ranges of frequency 100Hz-400 kHz for CNT-Zn /polyester composite. It can be observed from figure that that dielectric loss decreases with increasing of frequency, Also the value of tan□ increases with increasing of CNT-Zn content and modes of variation are associated with the presence of loss minimum at higher frequency for all samples. It has been pointed out [9] that the influence of filled content of CNT –Zn on the dielectric constant is strongly attributed to the increase of lattice defects of the materials at high concentration making space charge polarization dominant.

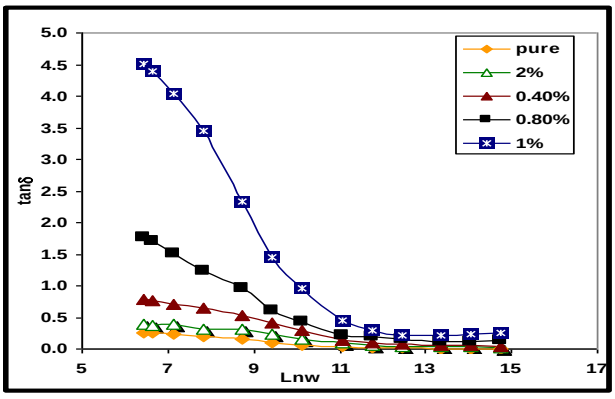

Fig.2: Variation of dielectric loss versus frequency for different concentrations of CNT-Zn /polyester composite

A.c conductivity

The variation of a.c conductivity with frequency of the CNT-Zn/polyester nanocomposite at different concentration filer of CNT-Zn was observed from Fig.3. As can be seen from Fig. 1, the amount of CNT in the composites strongly influences on the ac conductivity. The conductivity behavior can be divided according to the measured frequency. In the low frequencies region, the conductivity is constant and is taken to be the dc conductivity . Theoretically, this behavior may be modeled by transport taking place through the random free-energy barriers [10].When the frequency is increased, It is observed that the frequency variations of conductivity in the former graph is strongly related to a power law[11] :

$$\sigma(\omega)_{ac} = A\omega^{s} \text{----------(1)}$$

where, exponent s is found to be temperature dependent, A being a constant independent of frequency but dependent on temperature and ω is angular frequency exponent (s) dependent on the transport mechanism ,while at higher frequencies, the conductivity tends to stability. The phenomenon has been ascribed to relaxations caused by the motion of electrons or atoms. Such motion can involve hopping or tunneling between equilibrium sites [12]. Inspection of results indicates that σa.c. increases with increasing of CNT-ZN contents.

From these dependences we could estimate that the power law parameter s in above Equations close to 1. This supports the idea that polaron hopping plays an important role in charge carrier transport in materials with low resistivity in a broad range of relative humidity conditions. The variation of a.c. conductivity with frequency for the ZnO thin films is shown in Fig.3 It is seen that the a.c. conductivity increases with the increase of frequency and temperature. The a.c. conductivity is found to depend on the frequency it was related to the correlated barrier hopping type (CBH) mechanism .

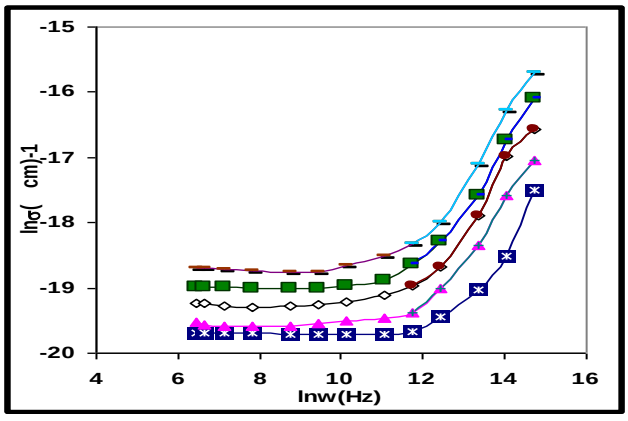

Fig. 3 Variation of a.c conductivity with frequencies at different concentration filer of CNT-Zn

The complex dielectric constant of a material medium is representing by two parts: ε = εr + εi, where εr is the real part (dielectric constant) and εi the imaginary part (dielectric loss). The ratio between έ and ε˝ define a loss tangent tan δ = ε˝ / έ. The corresponding real and imaginary parts of a.c. conductivity obey the following relations [13]

σa.c.=εo ω εr(ω) ----------(2)

whereεo is permittivity of free space(= 8.85 x10-12 F/m). The frequency dependence of εr and εi part of dielectric constant at various CNT-Zn content , for the investigated nanocomposite is presented in Fig. (4) and Fiq.(5), respectively.

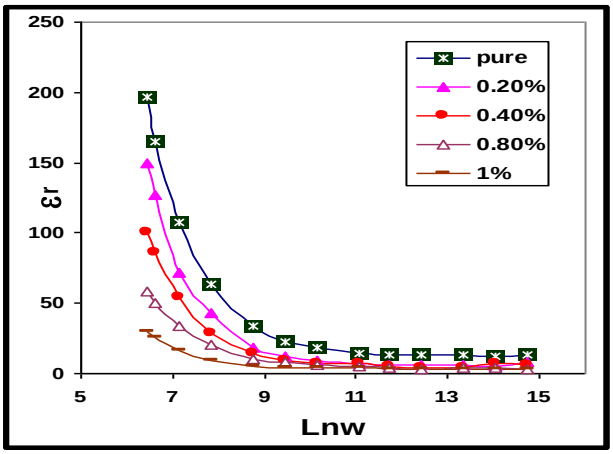

Fig. (4): Frequency dependence of εr of dielectric constant for CNT-Zn/polyester nanocomposite at various annealing temperatures

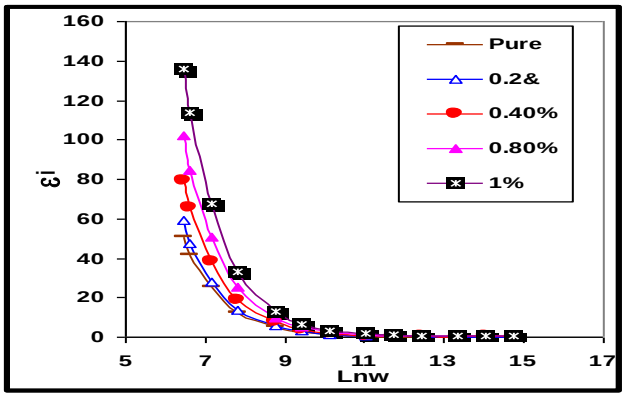

Fig. (5): Frequency dependence of εi of dielectric constant for CNT-Zn/polyester nanocomposite at various annealing temperatures

In general features are the rapid decrease of dielectric constant with both parts with increasing the frequency and reaches a constant value for all samples at room temperature due to the interfacial polarization only. The decreases of Ɛ with increasing frequency is the expected behavior in the most dielectric materials and this is due to dielectric relaxation involves the orientation polarization which in turns depends up on the molecular arrangement of dielectric to be material. So at higher frequencies , the rotational motion of the polar molecules of dielectric is not sufficient rapid for the attainment f equilibrium with the field , hence dielectric constant seems to be decreasing with frequency[14]. Very large values of dielectric constant are observed, especially at low frequency. This can be attributed to the fact that the electrode blocking samples is dominated mechanism at low frequency region [15].Also, it is clear from these figures that the values of εr decrease while values of εi increase by increasing CNT and Zn contents. This indicates that, the increases of CNT and Zn contents play a considerable role in dielectric constant. Fig.6 represents the relaxation time of the CNT-Zn/polyester nanocomposite at different concentration filer of CNT-Zn as a function of frequency .From this figures,we can see that the relaxation time decreases with increasing of frequency and CNT-Zn content in polyester matrix

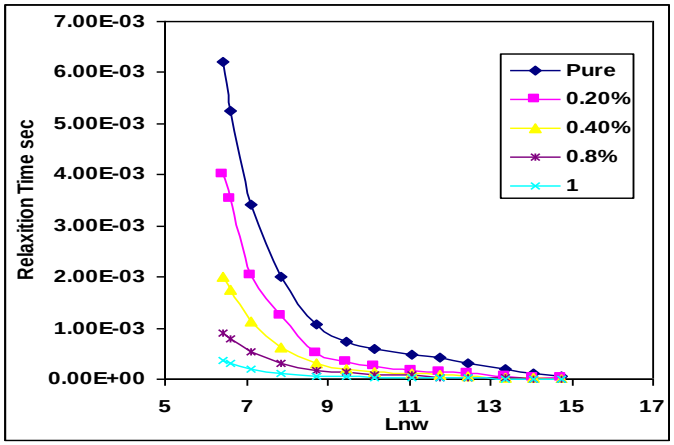

Fig. (6): Frequency dependence of Relaxation time for CNT-Zn/polyester nanocomposite at various annealing temperatures

Conclusion

composites of carbon nanotubes and zinc matrix have been successfully fabricated by a powder metallurgy method The A.C. conductivity results show that all samples strong temperature and frequency dependence where the exponent (s) decreases by increasing annealing temperature and the Corelated barrier hopping model is the most suitable for describing the a.c. conduction mechanism in the samples. Finally other conduction parameters have been interpreted on the basis of CBH mode. The dielectric constant (ε) and loss factor (tan δ) were found to be influenced by CNT contents.

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